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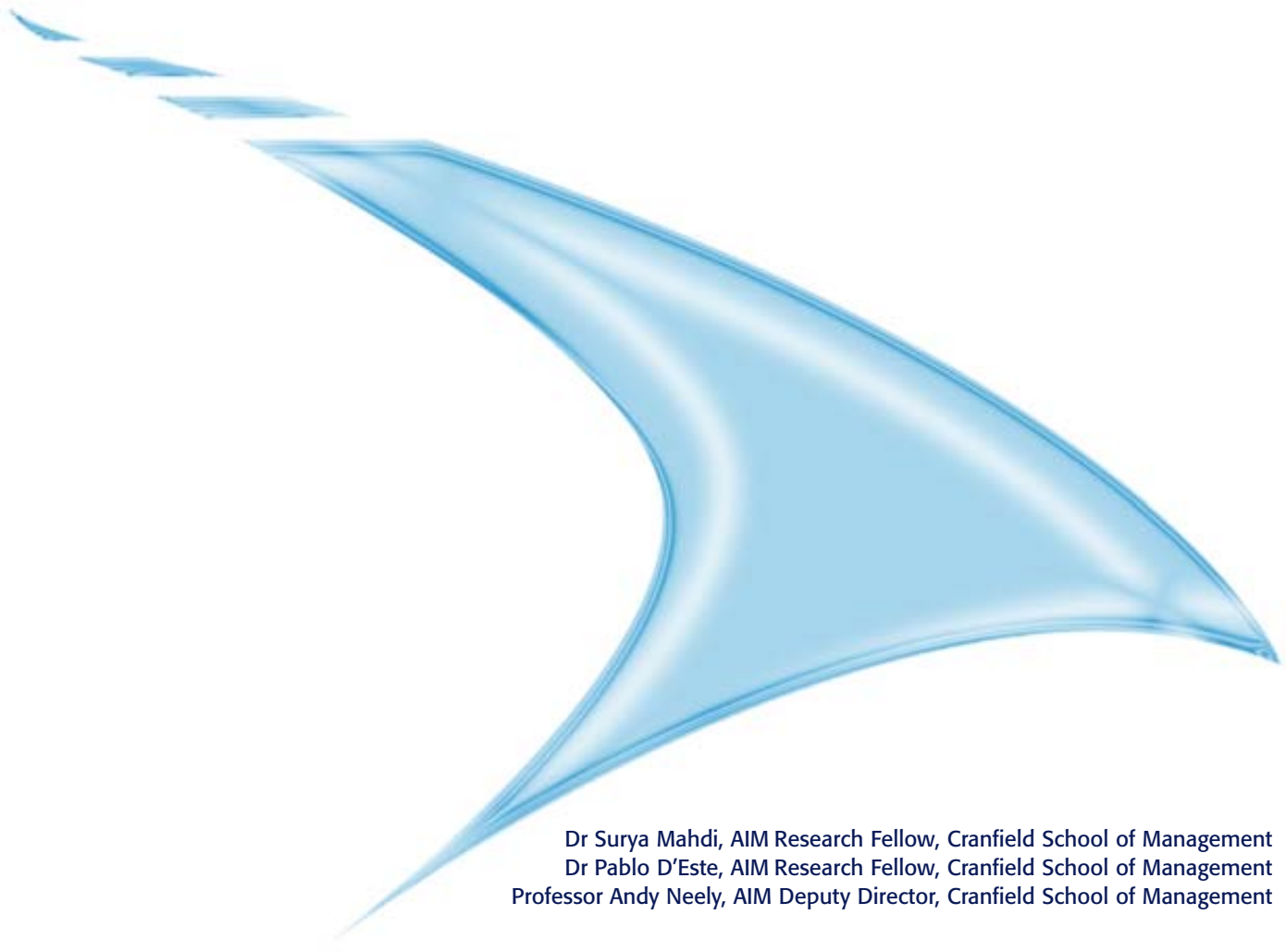

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A bibliometric analysis of RAE 2001[1]

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Contents

1 Assessing Research Performance

The question of how best to assess research performance is clearly of great concern. In December 2007, HEFCE launched a national consultation on the future of Research Assessment, proposing that a Research Excellence Framework replaces the current Research Assessment Exercise. Fundamentally the Research Excellence Framework involves a shift to metrics. Views on the effectiveness of metrics for assessing research are mixed, so in this report we seek to explore empirically the question of whether metrics based on citation counts are strongly correlated with peer review assessments of research quality. We use data from RAE 2001, covering all departments and all universities in the UK. At a more disaggregated level the data used in this study includes:

1 The individual submissions made to RAE 2001 – a database of 203,743 research output records, one for each output submitted in RAE 2001.

2 The citation counts for each of the submitted items when they are journal articles (141,789 of the original 203,743 items). We have interrogated the ISA Web of Science and produced citation counts for every article included in RAE 2001 where data is available. This gives us citation counts for 112,201 publications (55.1% of the original 203,743 submitted items).

3 The actual RAE 2001 scores produced and published by HEFCE. We contrast these scores – which are based on peer review – with those that would have been produced had bibliometrics, based on citation counts, been used in RAE 2001.

The findings of this analysis are:

1 Citation counts are a reasonable proxy for peer assessment in some subjects, such as Biological Sciences, Clinical Sciences, Chemistry and Psychology.

2 However, citation counts are a weak proxy for a large number of disciplines, including fields within Biomedical-related subjects and Engineering-related subjects. This is despite the fact that these subjects have good coverage in the Web of Science, in terms of the outputs submitted to RAE 2001.

3 As others have reported, the Web of Science offers only partial coverage in some subjects, and hence the use of bibliometrics becomes increasingly less valuable as we move from Biomedical, Physical Sciences and Engineering, to Socials Sciences, Literature and Arts and Humanities.

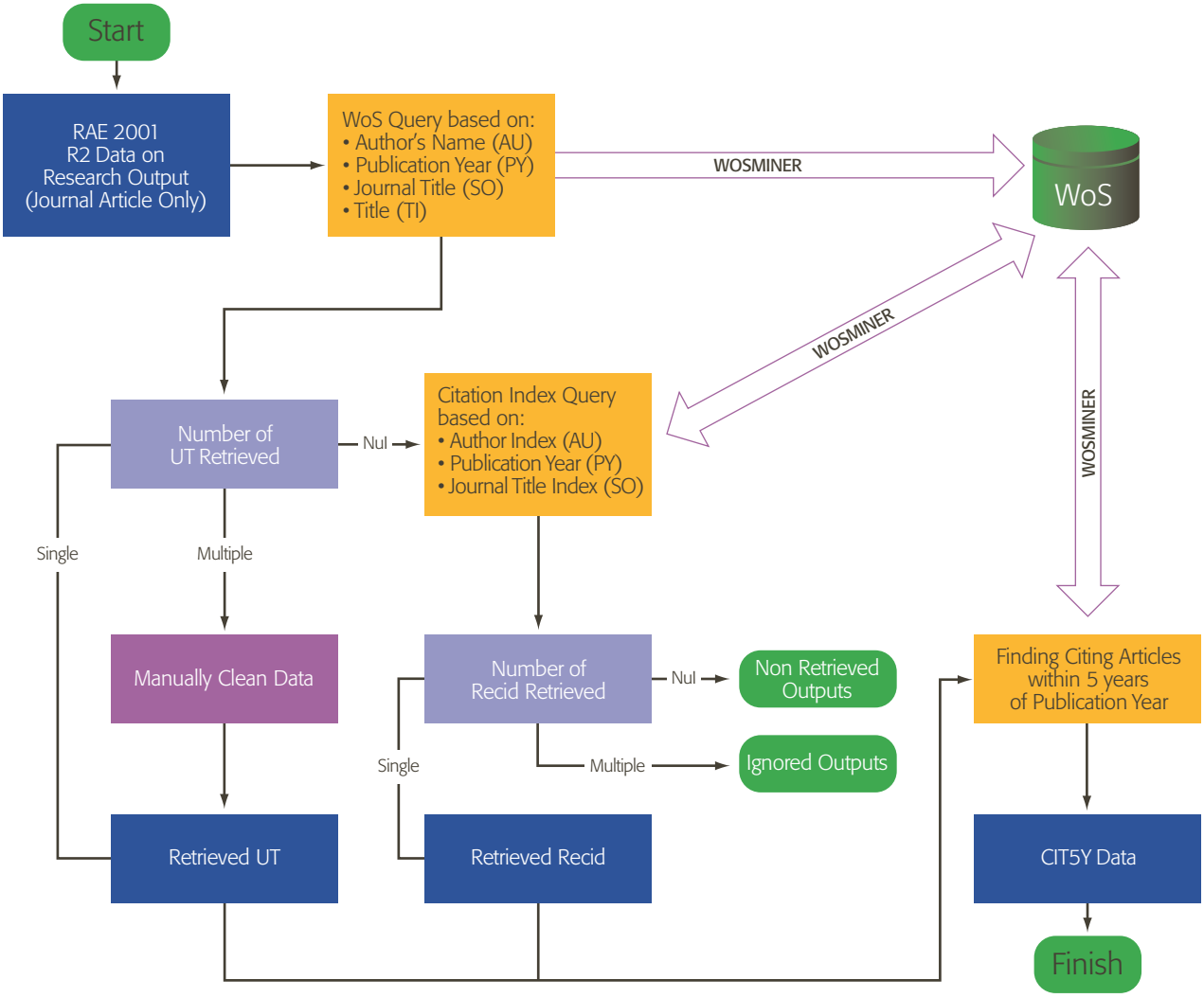
The remainder of this report consists of four sections. The second section explains the data used in the study and how these data were collected. The third presents descriptive statistics from the dataset, illustrating what the available data tell us about RAE 2001 journal article citations. The fourth section examines the extent to which there is a weak or strong rank-ordered correlation between citation counts and RAE 2001 score, for every discipline (i.e. Unit of Assessment) across all UK Universities. The fifth and final section discusses the results of this study and the implications for the current debate on the appropriateness of bibliometric indicators to measure research performance.

2 Data Sets and Sources

The data for RAE 2001 are published on the HERO website – www.hero.ac.uk. Complete copies of submissions, including data on individuals and their submitted publications are available. In total the HERO website contains information on 203,743 different research outputs from 53,455 submitting individuals. 69.59% of these submissions are journal articles (141,789). The citation count for each of these journal articles was looked up on the ISI Web of Science using customised software developed by the research team.

The algorithm used to link the individual items of RAE 2001 journal articles with the relevant citation counts is illustrated in Figure 1. This process resulted in a matching of 79.13% (112,201 from 141,789) of the journal articles included in RAE 2001 being identified in the Web of Science. The unmatched outputs included those which are either not indexed in the Web of Science (i.e. papers in journals not indexed in the Web of Science) and/or papers not cited by any Web of Science indexed articles.

Figure 1: Flowchart RAE 2001 – WoS Database Construction



As can be seen from Figure 1, the steps involved in looking up citation counts for individual articles were as follows. First, a query was submitted to Web of Science based on the authors' names, publication year, journal title and title of the journal article, in order to establish the match. Subsequently, the citation counts for the matched articles were retrieved. A cut off of citations within the first five years of the publication, including self-citation, was used. If the matches produced multiple hits, we ignored the records[3]. Also, we carried out an extended search based on the citation index of Web of Science for those records for which we could not find a match. Again, we ignored cases where multiple hits were produced.

Characteristics of the resultant database

The overall summary of the data collected, labelled as the RAE 2001 – WoS Database, is illustrated in Table 1. As the Table shows, not all the research outputs submitted for evaluation were journal articles. The submitted outputs included also: patents, book chapters, reports, new designs, artefacts, exhibitions, etc.

It can also be seen from this table that not all journal articles submitted for evaluation matched with the Web of Science data (we turn to the reasons for this matching problem in the following section).

Table 1: Summary of RAE 2001 – WoS Database

	Total Output	Journal Articles	Matched Journal Articles	Total Citations
Bio-Medical Sciences	54,134	52,150	48,422	1,457,940
Engineering and Physical Sciences	47,740	41,667	38,077	477,775
Social Sciences	53,099	33,715	18,851	102,505
Literature	16,089	5,553	2,437	2,974
Arts and Humanities	32,681	8,704	4,414	9,991
Total	203,743	141,789	112,201	2,051,185

Methodological limitations

Before reviewing the data in more detail, it is worth noting the methodological limitations of this approach. These fall into three generic categories – [i] types of research output considered, [ii] limitations of using citation counts and [iii] data sources.

Types of research output

Given the nature of the Web of Science and the fact that it consists predominantly of academic publications, this study focuses on academic journal publications. Clearly the decision to focus on academic journal publications undervalues other forms of research output, such as patents, books, case studies, engineering designs, compositions, works of art, etc. This narrowness of scope clearly disadvantages certain subjects and disciplines, notably those which do not see journal publications as their main or most significant research outputs.

[3] Multiple hits can occur if particular authors publish several articles in the same journal in the same year with similar titles and where the additional information given by the RAE 2001 data can not resolve the ambiguity.

Citation Counts

The limitations of citation analysis for research evaluation have been widely discussed in the literature (van Raan, 1988; Moed, 2005). In our study, we use the average of citations per journal article as our basic measure of research impact. This crude measure bears some limitations.

First, because the patterns of publications and citations differ considerably across disciplines, citation measures are often normalised by the average numbers of citations across the whole population of publications within a field. However, since our dataset is based only on the submitted papers[4], we do not have information of the whole population of papers for every scientific field, and therefore we cannot normalise by the average citation within a field. To attenuate this problem, we base our analysis on comparison within disciplinary fields only, thereby negating the need to normalise across entire fields.

Second, because the number of citations of a journal article can be influenced by self-citation, it is sometimes recommended that self-citation be excluded. The counter-argument is that those working at leading edge of a research field are likely to have to cite their own work if they are building on their previous contributions. Given the technical challenges of excluding self-citations as well as these balancing arguments, self-citation has been included in this study. Nevertheless, to limit the effect of the excessive use of self citation by particular individuals, we set a minimum threshold number of matched journal articles per institution within a disciplinary field[5].

Data Sources

The third set of limitations are inherent in the data sources used. The Web of Science does not comprehensively cover non-English journals and hence some could argue that important non-English publications will be missed in this analysis. However, it is unlikely that this bias will be a significant problem for most subject areas and UK higher education institutions, although there may be exceptions, for example, 'Welsh studies'.

A more significant issue is that not all RAE 2001 journal articles can be matched in the Web of Science and the proportion of the matched outputs varies widely across subject areas (UoA) and across institutions. This issue will be addressed in the following Section.

[4] The inclusion of submitted papers in a particular field is determined by the researcher and not by bibliometric journal field (which would have permitted a match with the categorisation established by the Web of Science). This difference between RAE 2001 unit of assessments and the bibliometric fields complicates the identification of the population boundary of the unit of assessment for the purpose of normalisation.

[5] The argument here is that while self-citations might inflate the count of citations for certain articles, such effect might not be systematic across different journal articles and individuals involved in RAE 2001 submission. Therefore, the larger the number of journal articles per institution we consider to compute averages, the less significant will be the impact of self-citations in our citation measures.

3 What Can the Data Tell Us About Citations?

This section presents the collected data. The section consists of two parts. In the first, we examine the degree to which journal articles submitted to RAE 2001 match with the Web of Science data. This information provides the boundary of the reliability and scope of our analysis. The second part of the section identifies the underlying citation patterns and discusses the variation across higher education institutions (within various units of assessment).

Variation in Coverage

As mentioned in section 2, 'only' 80% of journal articles submitted to the RAE 2001 could be found in the Web of Science. It is crucial to note that such coverage of journal articles in the Web of Science varies dramatically across disciplines.

Figure 2 displays a summary chart, highlighting the extent of this variation for the different 'units of assessment'. In this report we use the term 'unit of assessment' to refer to disciplinary field. In doing this, we follow the definitions established by the RAE 2001, where UK Higher Education Institutions were invited to submit their research activity for assessment to a number of subject-based Units of Assessment (UoAs). A total of 68 UoAs were defined, and they constitute the disciplinary fields we use in this report. In what follows, we use these two terms (disciplines and units of assessment) interchangeably.

The bars in red in Figure 2 refer to Biomedical-related fields; those in yellow refer to Engineering and Physical Sciences; in blue, Social Sciences; in green, Literature-related fields; and finally in grey, Arts and Humanities.

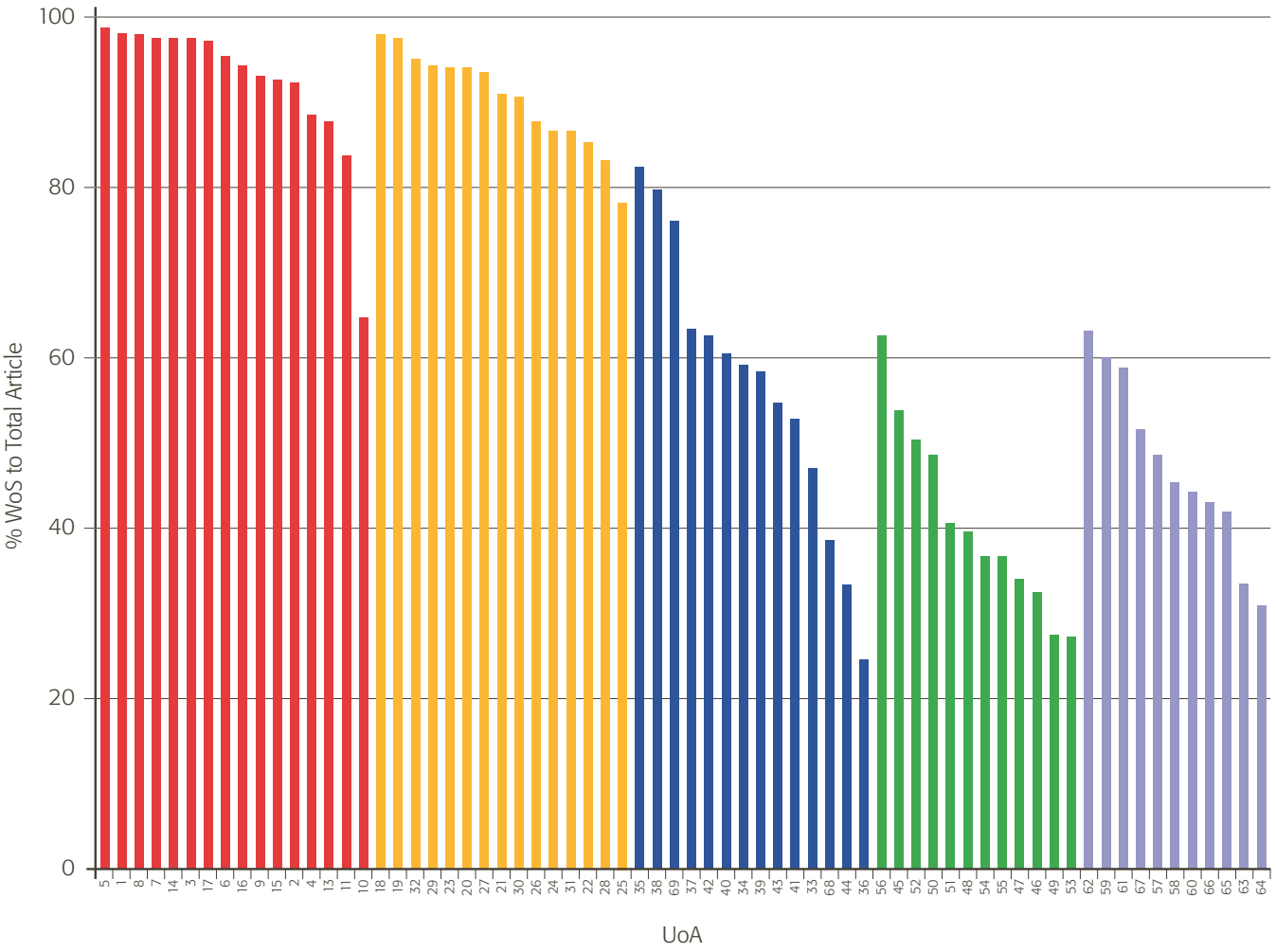
As Figure 2 clearly shows, Biomedical-related fields and Engineering and Physical Sciences are the two groups of fields with the highest proportions of journal articles matched in the Web of Science. While Literature-related fields and Arts and Humanities have the lowest coverage. Finally, Social Sciences disciplines show a wide variety of coverage, some disciplines being close to the former two groups (i.e. Biomedical and Engineering) while others are close to the latter two (Literature and Arts and Humanities). This pattern of coverage is consistent with the findings reported in HEFCE 2007.

With respect to the Biomedical-related fields, the units of assessment with the highest coverage are UoA 5 [Pre-clinical studies], where 98.7% of publications are identified; UoA 1 [Clinical laboratory sciences], where 97.8% of publications are identified; and UoA 8 [Pharmacology], where 97.7% of publications are identified. While the unit of assessment with the lowest coverage is: UoA 10 [Nursing], where 64.5% of journal articles are identified.

With respect to the Engineering and Physical Sciences, the units of assessment with the highest coverage are UoA 18 [Chemistry], where 97.9% of publications are identified and UoA 19 [Physics], where 97.4% of publications are identified. In this group, the unit of assessment with the lowest coverage is: UoA 25 [Computer Science], where 77.8% of journal articles are identified.

In Social Sciences, the highest coverage is found in UoA 35 [Geography], where 82.3% of publications are identified; while the lowest coverage is found in UoA 36 [Law], where only 24.1% of publications are matched.

Figure 2: Disciplinary Coverage of the Web of Science



In Literature related fields, the highest coverage is found in UoA 56 [Linguistics], where 62.2% of journal articles are matched; while the lowest coverage is found in the UoA 53 [Italian Studies], with a 26.8% coverage.

Finally, in Arts and Humanities, the highest coverage is found in UoA 62 [Philosophy], with a 63.1% of coverage, while the lowest coverage is found in UoA 64 [Arts and Design], with a 29.5% coverage.

This variation in coverage across groups of fields is partly caused by the fact that even though Web of Science has a comprehensive coverage of journals in certain fields, it has relatively poor coverage in others. In particular, in the area of Biomedical and Physical Sciences, journals are highly covered; while in areas such as Arts and Humanities, the journals in which researchers publish their work are poorly covered in the Web of Science.

Variation in Citations

This sub-section analyses the underlying pattern of citations in the data. Of particular importance is the extent to which citation patterns differ across different Units of Assessment. Figure 3 illustrates this.

First, the average citation per paper varies considerably across disciplines. As can be seen in Figure 3, Biomedical-related fields tend to have a higher average number of citations per paper, compared to all other disciplinary groups. For example, the highest average citation per paper for a Biomedical-related field is 46 for UoA 6 [Anatomy]; while the lowest average citation per paper within this group is 7.9 for UoA 10 [Nursing].

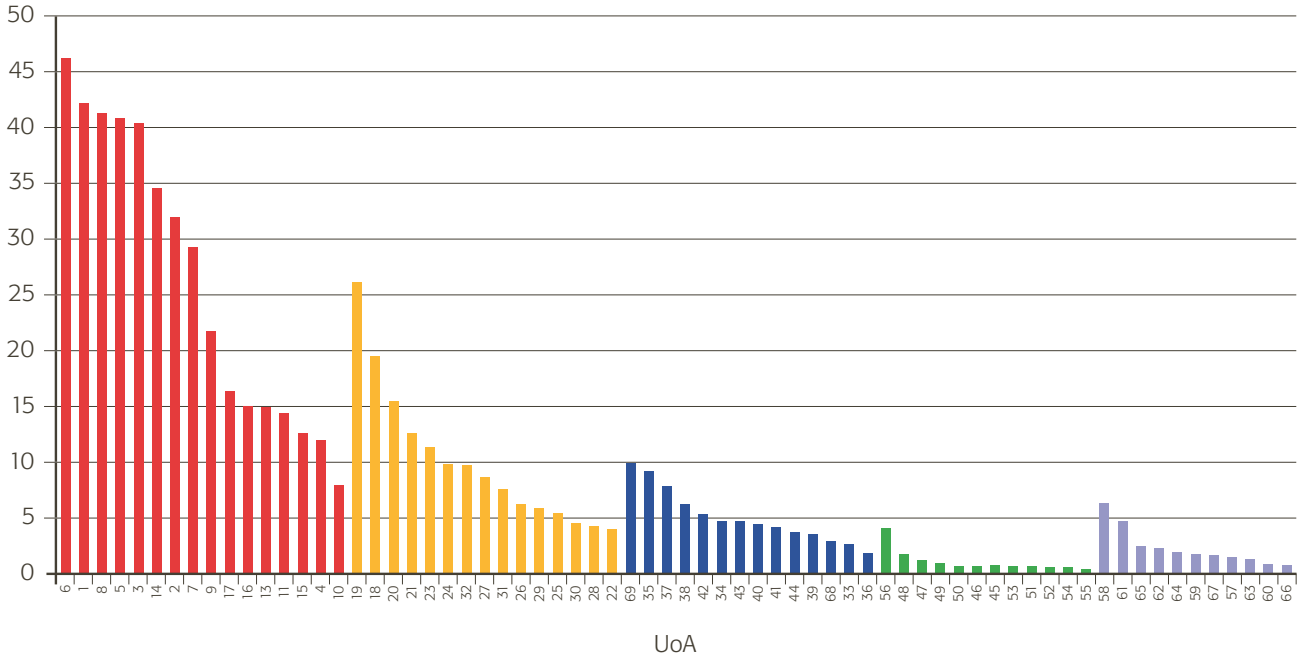
In Engineering and Physical Sciences, the highest average citation per paper is 26.1 for UoA 19 [Physics]; while amongst the disciplines with the lowest average citation are UoA 30 [Mechanical Engineering], UoA 28 [Civil Eng.] and UoA 22 [Pure Mathematics] – 4.6, 4.3 and 3.9 citations per paper respectively.

In Social Sciences, the highest value corresponds to UoA 69 [Sport related-subjects], with an average citation of 9.6; while the lowest corresponds to UoA 36 [Law], 1.8. In Literature related fields, the highest average citation corresponds to UoA 56 [Linguistics] (4.1), while the lowest corresponds to [Iberian and Latinoamerican Languages] – 0.3. Finally, in Arts and Humanities the highest average citation is found in UoA 58 [Archaeology] – 6.5, while the lowest is found in UoA 66 [Drama, dance and performing arts] – 0.5.

These results are consistent with those of other studies, such as the HEFCE 2007 Report, which show that journal articles in Engineering-related subjects have a lower number of citations per paper than Biomedical-related and Physical Science papers.

The variation in average numbers of citations per paper across disciplines may be caused by a number of factors. Clearly there are cultural dimensions, with some disciplines tending to reference more previous work than others. There may also be subject-related factors. For example, more intellectually mature disciplines may have wider agreement about important developments and contributions and hence higher citations counts. Whereas broader and less well developed disciplines may still be struggling with fundamental arguments about the nature and content of their subject, with less agreement about which contributions matter.

Figure 3: Variation of the average citations across various UoA



One important implication of the variation across disciplines in terms of average citations per paper, is that cross disciplinary comparisons are fraught with methodological challenges, unless the citation data are normalised by subject. To overcome this challenge, the current study focuses its analysis on the variation *within* disciplines rather than *between* disciplines.

Another important issue is related to the degree of citation heterogeneity across institutions within each UoA. In other words, given that there is variation across disciplines in terms of average numbers of citations, what evidence is there that there is variation within the disciplines themselves, but across institutions? To explore this question we compare the average numbers of citations across five groups with an equal number of HEIs (i.e. quintiles) within each unit of assessment. We firstly ranked institutions according to their average numbers of citations and then grouped them in five groups of equal size (in terms of number of institutions). Finally, we examined the extent to which the 5 groups differ significantly in terms of their means of average citation. For the purpose of illustration, we show the case of Chemistry below. As can be seen, there is a significant difference across average citations for the five groups of institutions (see Figure 4) indicating the heterogeneity of citation counts across institutions in this UoA.

Figure 4: Variation of the average citations across different group of HEIs within UoA 18 [Chemistry]

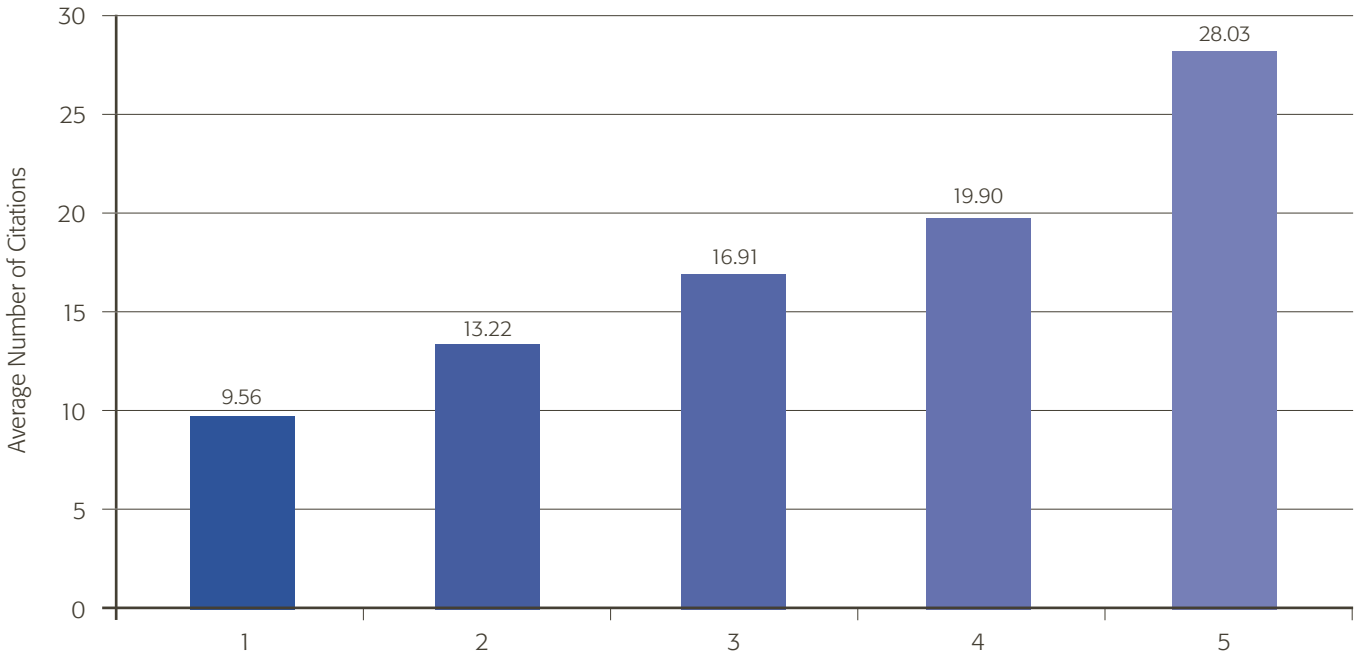


Table 2 shows the summary table for all UoAs that contain at least 20 institutions which have 20 or more matched RAE 2001-Web of Science journal articles. ANOVA test between quintiles shows significant differences in means in those UoAs, confirming the heterogeneity of the average of citations counts across different institutions. This effect is more conspicuous amongst UoAs which have higher average citation counts.

Table 2: Summary of Average Citation Across Different Quintiles of Institutions for selected UoA (within bracket: Number of Russell Group Institutions to total institutions per quintile)

UoA	Number of Institutions	Quintiles				
		1	2	3	4	5
1	24	23.7492 (1/5)	31.435 (2/5)	38.173 (3/5)	49.8081 (5/5)	61.7674 (3/4)
2	30	19.5405 (2/6)	25.824 (1/6)	28.1918 (5/6)	31.4181 (4/6)	53.769 (5/6)
3	29	25.1033 (3/6)	33.0074 (1/6)	38.6822 (6/6)	43.2943 (5/6)	55.5719 (4/5)
10	33	3.7174 (0/6)	5.668 (1/6)	7.4453 (3/6)	9.3191 (3/6)	15.2106 (1/6)
11	51	6.3671 (0/11)	9.448 (2/10)	11.5991 (1/10)	16.1839 (3/10)	22.1296 (2/10)
13	67	5.9308 (1/14)	9.0139 (1/13)	12.032 (1/14)	15.695 (6/13)	22.6075 (6/13)
14	70	13.618 (3/14)	21.8368 (4/14)	28.7886 (7/14)	37.8522 (8/14)	56.1408 (6/14)
18	45	9.5552 (0/9)	13.2204 (2/9)	16.9108 (4/9)	19.9042 (5/9)	28.0303 (6/9)
19	45	12.8042 (1/9)	17.3503 (2/9)	22.7522 (4/9)	26.0981 (6/9)	37.3016 (4/9)
20	24	7.8557 (2/5)	12.2142 (1/5)	14.0217 (3/5)	16.6209 (3/5)	23.0945 (3/4)
21	27	6.5844 (0/6)	8.6575 (0/5)	11.1731 (1/6)	14.3122 (2/5)	18.6374 (2/5)
22	37	1.99 (2/8)	2.981 (3/7)	3.6657 (4/7)	4.2712 (3/7)	5.6128 (5/7)
23	43	4.8205 (0/9)	6.2917 (3/9)	7.8958 (3/8)	11.5848 (4/9)	22.3006 (5/8)
24	32	3.6171 (2/7)	4.9045 (3/6)	6.534 (2/7)	10.2348 (2/6)	24.794 (4/6)
25	53	2.9587 (2/11)	3.8412 (2/11)	4.6137 (3/10)	6.4394 (4/11)	8.9868 (6/10)
26	41	2.2741 (0/9)	3.6307 (0/8)	4.522 (0/8)	5.5492 (1/8)	11.1395 (4/8)
28	25	2.6078 (3/5)	3.3496 (2/5)	4.1736 (4/5)	4.6439 (3/5)	5.914 (2/5)
29	40	2.6535 (2/8)	3.4171 (3/8)	4.3566 (2/8)	5.6718 (5/8)	9.9724 (4/8)
30	40	2.4712 (3/8)	3.5342 (3/8)	4.0634 (3/8)	4.9869 (5/8)	6.5986 (5/8)
32	23	3.3588 (1/5))	6.4275 (1/5))	8.7181 (0/4)	10.5128 (1/5)	15.0309 (4/4)
35	52	4.4635 (0/11)	7.194 (3/10)	8.3941 (4/11)	9.8768 (3/10)	14.0068 (5/10)
38	38	2.7514 (2/8)	3.7041 (1/8)	5.0274 (2/7)	6.2616 (3/8)	10.0682 (3/7)
39	22	1.7404 (2/5)	2.9772 (2/4)	3.6365 (1/5)	4.5662 (2/4)	6.0691 (1/4)
40	22	2.3278 (2/5)	3.6596 (1/4)	4.7483 (2/5)	5.2315 (3/4)	6.624 (0/4)
42	24	2.8381 (0/5)	4.3402 (1/5)	5.1382 (3/5)	6.7052 (1/5)	9.8037 (1/4)
43	68	1.9962 (0/14)	3.0236 (1/14)	3.9073 (3/13)	4.9341 (6/14)	6.9348 (3/13)
59	30	0.8178 (3/6)	1.2188 (2/6)	1.3633 (3/6)	1.6276 (3/6)	2.6096 (2/6)
68	35	1.6398 (1/7)	2.051 (0/7)	2.7053 (3/7)	3.4568 (4/7)	4.577 (3/7)

Within these quintiles, Russell group institutions are more likely to be situated in the top groups (See Table 2 within bracket). In some UoAs (e.g. UoA 1), they even represent the majority of the institutions that are situated in the top two quintiles (Group 4 and 5). This result is not surprising given the established reputation of most of Russell group institutions in various academic disciplines.

Nevertheless, some Russell group institutions are found to be situated in the bottom two groups (Group 1 and 2) (e.g. in UoA 14). Is this position also reflected or predicted by their RAE score? Are citations correlated with RAE 2001 scores? The answer to these questions will be discussed in the next section.

4 Are Citations Correlated with RAE 2001 Scores?

At the heart of current debates about what should replace the Research Assessment Exercise in the UK are questions of whether metrics based on bibliometric data would provide a good proxy for RAE scores based on peer review. We investigate this issue by examining the extent to which indicators of research impact based on citations to journal articles are strongly correlated with the scores obtained on the basis of RAE 2001, for each unit of assessment.

The measure of research impact for a particular institution within a unit of assessment (e.g. Chemistry at the University of Sussex) is computed by taking the average citation count (within the five first years after publication) of all journal articles submitted by that institution.

By using a measure of research impact based on average citations, we are able to capture the wide range of variation across HEIs in the large majority of units of assessment. We have, however, compared these measures of research impact with those based on the median, and the results are largely indistinct, as both measures are highly correlated to each other. Measure based on average citations have also been used by other studies examining research performance (Norris and Oppenheim, 2003; Leiden University, 2007; and HEFCE, 2007).

In order to examine whether bibliometric measures and peer review assessments produce comparable results we test the ranking of institutions produced by these two measures. To test the extent to which these two rankings are highly correlated, we use Spearman rank-order correlations (also used by Norris and Oppenheim, 2003).

Additionally, in order for these correlations to be meaningful, we have imposed two conditions. First, we only consider institutions that have 20 or more journal articles matched in the Web of Science in the specific Unit of Assessment being studied. This means that we have a reasonable number of publications from which to derive our measure of research impact. Second, we only include in our analysis those Units of Assessment that at least contain 20 of those institutions (that have 20 or more journal articles matched).

The overall results from the rank-order correlations can be seen in Table 3. For a substantial proportion of the units of assessment examined (i.e. 19 out of 28), the correlations are statistically significant, indicating that both metrics based on citations and assessment based on peer review portray a similar picture in terms of the ranking of institutions within a particular unit of assessment. It is important to note, however, that these correlations, while statistically significant, are not necessarily high. More specifically, while some cases such as Chemistry (UoA 18) show a correlation above 0.7 (green highlight), a substantial proportion of cases present figures that range between 0.4 and 0.7 (orange highlight)[6]. This indicates that while the two measures of research impact are positively correlated for 19 units of assessment, the ranking of institutions that emerge from the two measures is far from identical.

[6] For UoA 68, the coverage is red highlighted since the value is so low.

Table 3: Rank-ordered correlations between average numbers of citations and RAE 2001 scores

UoA	Description	Group of Disciplines	Spearman Corr. Coef	Sig.	Obs	Cover (% Match)	AvgCit (>=20 Match)
1	Clinical Lab. Sciences	BIOMEDICAL	0.821	0	24	97.8	40.12
2	Comm.-based Clin. Subjs	BIOMEDICAL	0.604	0	30	91.9	31.75
3	Hospital-based Clin. Subjs	BIOMEDICAL	0.573	0.001	29	97.3	38.56
10	Nursing	BIOMEDICAL	0.202	0.261	33	64.5	8.09
11	Other Allied to Medicines	BIOMEDICAL	0.641	0	51	83.5	13.01
13	Psychology	BIOMEDICAL	0.734	0	67	87.3	12.93
14	Biological Sciences	BIOMEDICAL	0.723	0	70	97.4	31.65
18	Chemistry	ENGPHYSCAL	0.789	0	45	97.9	17.52
19	Physics	ENGPHYSCAL	0.685	0	45	97.4	23.26
20	Earth Sciences	ENGPHYSCAL	0.754	0	24	93.6	14.41
21	Environmental Sciences	ENGPHYSCAL	0.562	0.002	27	90.7	11.65
22	Pure Mathematics	ENGPHYSCAL	0.313	0.059	37	85.1	3.66
23	Applied Mathematics	ENGPHYSCAL	0.559	0	43	93.7	10.37
24	Statistics and OR	ENGPHYSCAL	0.563	0	32	86.1	9.71
25	Computer Sciences	ENGPHYSCAL	0.522	0	53	77.8	5.31
26	General Engineering	ENGPHYSCAL	0.547	0	41	87.5	5.35
28	Civil Engineering	ENGPHYSCAL	0.038	0.855	25	82.8	4.14
29	Elec. and Electron. Eng.	ENGPHYSCAL	0.291	0.069	40	94	5.21
30	Mech. Aeron. Manuf. Eng.	ENGPHYSCAL	0.194	0.231	40	90.1	4.33
32	Metall. and Materials	ENGPHYSCAL	0.673	0	23	94.4	8.54
35	Geography	SOCSCIENCE	0.383	0.005	52	82.4	8.7
38	Economics and Econometr.	SOCSCIENCE	0.677	0	38	79.5	5.46
39	Politics and Inter. Studies	SOCSCIENCE	0.171	0.447	22	58.2	3.7
40	Soc. Policy and Admin.	SOCSCIENCE	0.302	0.172	22	60.2	4.43
42	Sociology	SOCSCIENCE	-0.099	0.646	24	62.1	5.6
43	Business and Management	SOCSCIENCE	0.782	0	68	54.8	4.12
59	History	ARTSHUMAN	0.013	0.944	30	60.3	1.53
68	Education	SOCSCIENCE	0.360	0.338	35	38.3	2.89

Moreover, as Table 3 also shows, for about a third of the units of assessment examined (9 out of 28), the correlations are not significant (red highlight). In some cases this is due to the low proportion of journal articles matched in the Web of Science (see last column of Table 3), such as in the case of: Politics and International Studies (UoA 39), Social Policy and Administration (UoA 40), Sociology (UoA 42) or History (UoA 59). In these cases, it might be that a substantial proportion of the journals relevant in these disciplines are not fully covered in the Web of Science, and therefore, citations from the journal articles matched in the Web of Science provide only a partial picture of the impact of their research activities.

However, in cases such as Mechanical Engineering, Civil Engineering or Electrical and Electronic Engineering, where the coverage of journal articles in the Web of Science is comparatively high (always above 80%), the reasons why the two measures of research impact display a non-significant correlation is more difficult to trace. It is true that, when compared to Biomedical related fields, the research outputs in these three Engineering fields embrace more than only journal articles.

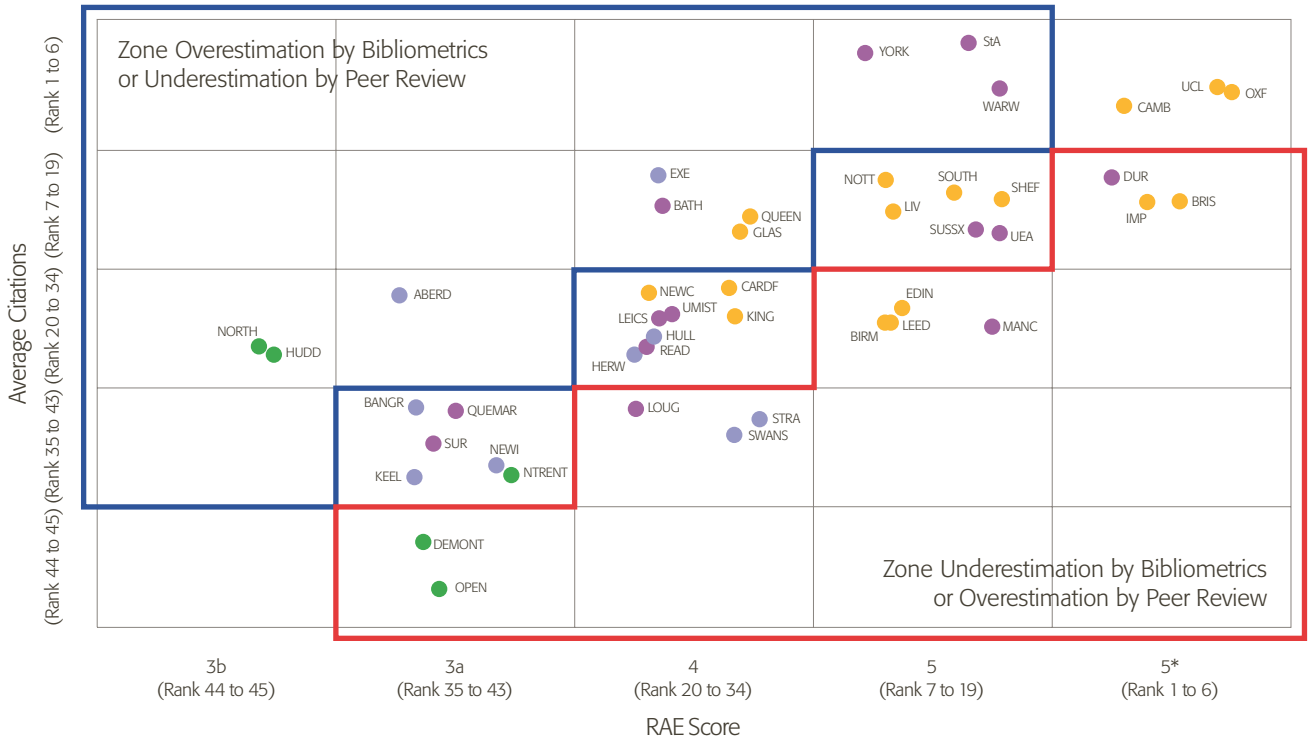
However, when these three Engineering disciplines are compared to the other broadly defined groups of disciplines (i.e. Literature, Social Sciences and Arts and Humanities), journal articles represent a relatively large proportion of total research outputs. In any case, the high degree of discrepancy between the two measures of research impact in the case of Engineering fields, calls for a cautionary approach in the use of bibliometric data as the main criteria for research evaluation for Engineering. One hypothesis would be that fields like Engineering do not cite much, making them materially different to other fields (See Table 3 Column 8). Hence basing assessment on citations alone is risky.

We have chosen randomly three units of assessment, to illustrate the three different patterns discussed above: Chemistry (UoA 18), to illustrate a case of a strong alignment between the two measures of research impact; Geography (UoA 35), to illustrate a case where the correlation between the two measures is low, although still statistically significant; and finally, Mechanical Engineering (UoA 30), to illustrate a case in which the two measures of research impact have no statistically significant correlation.

To illustrate the alignment between the RAE score and the average citation measure, we plot RAE scores against average numbers of citations. If the two measures were perfectly aligned, we would expect that all institutions would be positioned on the diagonal. The x-axis corresponds to institutional grouping according to RAE 2001, while the y-axis corresponds to average numbers of citations[7]. Units of Assessment which fall below the diagonal represent an overestimate of institutional research impact by peer review, while those above the diagonal would represent an underestimate. Orange dots correspond to the Russell group institutions. Pink dots correspond to the 1994 group institutions. Green dots correspond to the Alliance of Non-Aligned universities (currently known as University Alliance group) while light blue dots correspond to those which are not associated with any particular group of Higher Education institutions[8].

As Figure 5 shows, there is a close alignment between RAE scores and the average numbers of citations for UoA 18 (Chemistry). This can be observed by the fact that the majority of HEIs are situated within and around the diagonal grids. This picture reflects the results from the high correlation coefficient presented in Table 3.

Figure 5: Correlation between RAE score and the average citation measurement in UoA 18 [Chemistry]



[7] The grouping of institutions according to the average citation in every diagram refers to the expected grouping according to RAE institutional grouping.

[8] Institutions which are affiliated with the Campaigning for Mainstream Universities (currently known as 'Million+' group) will appear as red dots in the future graphs.

The cases that have similarity with Chemistry (correlation around and above 0.8) are relatively few (6 out of 28). Therefore, the close alignment between the two measures is specific and can not be generalised to all UoAs.

Figure 6 represents the cases where the correlation coefficient is not high although it is still statistically significant. As it can be seen in Figure 6, which presents data for Geography, a large proportion of HEIs are not exactly situated in the diagonal grids. In other words, the quality of some institutions' research is overestimated by their RAE score, while others have research that is apparently underestimated by RAE score. This example reflects the majority of disciplines analysed in this study (12 out of 28) for which the two measures of performance provide conflicting rankings of institutions.

Finally, Figure 7 represents the cases where the correlation coefficient is not statistically significant. Figure 7 presents data on Mechanical, Aeronautical and Manufacturing Engineering and there is no obvious correlation between RAE score and the average number of citations. This pattern represents 36% (10 out of 28) of the UoAs.

In short, since only a fifth of the UoA analysed conform to a pattern of high alignment between the two measures of performance (while the others show either weak or no correlation between the two measures), careful consideration is required before using bibliometric data as the main criteria for research evaluation.

Figure 6: Correlation between RAE score and the average citation measurement in UoA 35 [Geography]

Figure 7: Correlation between RAE score and the average citation measurement in UoA 30 [Mechanical, Aeronautical and Manufacturing Engineering]

5 Implications for Policy and the New Research Excellence Framework

The analysis presented in this report has some important implications for policy in terms of assessing research performance. First, it is clear that bibliometric cannot be used to assess all academic disciplines. This statement applies not just to those subjects with relatively poor coverage in the Web of Science, but also to some Units of Assessment in Engineering and Physical Research which have good coverage in the Web of Science.

Second, one has to question whether published output in academic journals is the most appropriate form of dissemination. For some Units of Assessment this is clearly not the case and yet both the Research Assessment Exercise and the current proposals for the Research Excellence Framework, privilege journal publication above other forms of output. If innovation lies at the heart of a developed economy and we want HEIs to have an impact on society at large, then we need to find assessment methods that recognise and encourage engagement as well as scholarship.

This leads to a third point – namely the multi-dimensionality of research performance and indeed, institutional mission. Reducing research success to a limited number of dimensions might not be a wise idea, even for academic disciplines whose research performance can be well represented through publication. Research productivity and research quality are just two specific components of overall higher education research performance. Other dimensions include contribution to the society, engagement with users, etc. Yet we do not appear to have good methods for assessing these currently.

Ultimately, the use of citation counts in research assessment may not be practical since its measurement is not a straightforward process for at least two reasons:

- First, there is time-lag constraint. This study, conducted in 2006, draws on data from RAE 2001. We have used a cutoff of citations within five years of publication. If the same method were adopted for the next research assessment exercise, to be held in 2013, the latest publication date for work that could be included would be 2008. Given that much of the work published in academic journals is 2-3 years old by the time of its publication due to the delays in the publishing and peer review cycle, any assessment based on citations would be looking at work that was seven-eight years old at the time of assessment. Is this an appropriate basis on which to make future funding decisions? Would we be better allocating research funding via the peer review processes employed by research councils and their equivalent?

- Second, due to the peculiarity of the particular database used, certain important publications may not be indexed by the database and therefore it will be difficult to systematically track their citation patterns. Thus the value of research output is underestimated. As this study shows, this is particularly the case for the Arts and Humanities, Literature and Social Sciences, where the proportion of journal articles matched in the Web of Science is comparatively low.

Clearly continuing with the current Research Assessment Exercise is not desirable. The institutional and administrative burden it imposes is excessive and the behavioural consequences for individual academics are becoming increasingly dysfunctional. Replacing the Research Assessment Exercise with a Research Excellence Framework, based on metrics, however, may not be an appropriate solution. A particular concern stems from the likely behavioural consequences of an assessment system involving citations. The Academy's relevance is already questioned by commentators who point to large sections of the scholarly community where academics talk primarily to other academics. Given that citation counts – calculated through the Web of Science – are a function of how many other academics cite your work, the likely behavioural consequence of an assessment method based on citations is that there will be an increased propensity for academics to spend their time talking with other academics. Clearly academic debate is important, but academic debate already takes place and the Academy has many outlets for such discussion. Surely our national system for assessing research should recognise and encourage diversity in institutional mission and disciplinary approach. We do not need an assessment methodology that privileges one dimension of research. Instead we need a system that celebrates research success in all of its guises.

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Appendix A: List of Unit of Assessment in RAE 2001

UoA	Description	Group
1	Clinical Laboratory Sciences	BIOMEDICAL
2	Community-based Clinical Subjects	BIOMEDICAL
3	Hospital-based Clinical Subjects	BIOMEDICAL
4	Clinical Dentistry	BIOMEDICAL
5	Pre Clinical Studies	BIOMEDICAL
6	Anatomy	BIOMEDICAL
7	Physiology	BIOMEDICAL
8	Pharmacology	BIOMEDICAL
9	Pharmacy	BIOMEDICAL
10	Nursing	BIOMEDICAL
11	Other Studies and Professions Allied to Medicine	BIOMEDICAL
13	Psychology	BIOMEDICAL
14	Biological Sciences	BIOMEDICAL
15	Agriculture	BIOMEDICAL
16	Food Science and Technology	BIOMEDICAL
17	Veterinary Science	BIOMEDICAL
18	Chemistry	ENGPHYSIC
19	Physics	ENGPHYSIC
20	Earth Sciences	ENGPHYSIC
21	Environmental Sciences	ENGPHYSIC
22	Pure Mathematics	ENGPHYSIC
23	Applied Mathematics	ENGPHYSIC
24	Statistics and Operational Research	ENGPHYSIC
25	Computer Science	ENGPHYSIC
26	General Engineering	ENGPHYSIC
27	Chemical Engineering	ENGPHYSIC
28	Civil Engineering	ENGPHYSIC
29	Electrical and Electronic Engineering	ENGPHYSIC
30	Mechanical Aeronautical and Manufacturing Engineering	ENGPHYSIC
31	Mineral and Mining Engineering	ENGPHYSIC
32	Metallurgy and Materials	ENGPHYSIC
33	Built Environment	SOCSCIENCES
34	Town and Country Planning	SOCSCIENCES
35	Geography	SOCSCIENCES
36	Law	SOCSCIENCES
37	Anthropology	SOCSCIENCES
38	Economics and Econometrics	SOCSCIENCES

UoA	Description	Group
39	Politics and International Studies	SOCSCIENCES
40	Social Policy and Administration	SOCSCIENCES
41	Social Work	SOCSCIENCES
42	Sociology	SOCSCIENCES
43	Business and Management Studies	SOCSCIENCES
44	Accounting and Finance	SOCSCIENCES
45	American Studies	LITTLANGUAGE
46	Middle Eastern and African Studies	LITTLANGUAGE
47	Asian Studies	LITTLANGUAGE
48	European Studies	LITTLANGUAGE
49	Celtic Studies	LITTLANGUAGE
50	English Language and Literature	LITTLANGUAGE
51	French	LITTLANGUAGE
52	German Dutch and Scandinavian Languages	LITTLANGUAGE
53	Italian	LITTLANGUAGE
54	Russian Slavonic and East European Languages	LITTLANGUAGE
55	Iberian and Latin American Languages	LITTLANGUAGE
56	Linguistics	LITTLANGUAGE
57	Classics Ancient History Byzantine and Modern Greek Studies	ARTSHUMANITY
58	Archaeology	ARTSHUMANITY
59	History	ARTSHUMANITY
60	History of Art Architecture and Design	ARTSHUMANITY
61	Library and Information Management	ARTSHUMANITY
62	Philosophy	ARTSHUMANITY
63	Theology Divinity and Religious Studies	ARTSHUMANITY
64	Art and Design	ARTSHUMANITY
65	Communication Cultural and Media Studies	ARTSHUMANITY
66	Drama Dance and Performing Arts	ARTSHUMANITY
67	Music	ARTSHUMANITY
68	Education	SOCSCIENCES
69	Sports-related Subjects	SOCSCIENCES

Appendix B: List of Institutions Returning to RAE 2001

Code	Institution Name	Abbrev.	Group[9]
H-0001	Open University	OPEN	NONALIGNED
H-0002	Cranfield University	CRA	NONALIGNED
H-0003	Royal College of Art	RCART	NOTAFFILIATED
H-0006	RCN Institute	RCN	NOTAFFILIATED
H-0008	Bretton Hall	BRETT	NOTAFFILIATED
H-0009	Buckinghamshire Chilterns University College	BCU	NOTAFFILIATED
H-0010	Central School of Speech and Drama	CSPCH	NOTAFFILIATED
H-0011	Chester College of HE	CHEST	NOTAFFILIATED
H-0012	Canterbury Christ Church University College	CHRCH	NOTAFFILIATED
H-0013	York St John College	YJOHN	NOTAFFILIATED
H-0014	College of St Mark & St John	CSTM&J	NOTAFFILIATED
H-0015	Dartington College of Arts	DCA	NOTAFFILIATED
H-0016	Edge Hill College of HE	EDGEH	NOTAFFILIATED
H-0017	Falmouth College of Arts	FALM	NOTAFFILIATED
H-0018	Harper Adams University College	HARP	NOTAFFILIATED
H-0019	Homerton College Cambridge	HOMER	NOTAFFILIATED
H-0020	Kent Institute of Art and Design	KENTI	NOTAFFILIATED
H-0021	King Alfred's College Winchester	KALF	NOTAFFILIATED
H-0023	Liverpool Hope	LIVHO	NOTAFFILIATED
H-0024	The London Institute	LINST	NOTAFFILIATED
H-0026	University of Luton	LUT	CMU
H-0027	University College Northampton	UCN	CMU
H-0028	Newman College	NEWM	NOTAFFILIATED
H-0031	University of Surrey Roehampton	ROEH	CMU
H-0032	Rose Bruford College	ROSE	NOTAFFILIATED
H-0033	Royal Academy of Music	RAMUS	NOTAFFILIATED
H-0034	Royal College of Music	RCMUS	NOTAFFILIATED
H-0035	Royal Northern College of Music	RNMUS	NOTAFFILIATED
H-0037	Southampton Institute	SOINST	CMU
H-0038	St Martin's College	MARTC	NOTAFFILIATED
H-0039	St Mary's College	MARYC	NOTAFFILIATED
H-0040	Trinity and All Saints	TAS	NOTAFFILIATED
H-0044	The Surrey Inst. of Art and Design University College	SURART	NOTAFFILIATED
H-0046	University College Worcester	WORC	NOTAFFILIATED
H-0047	Anglia Polytechnic University	APU	CMU
H-0048	Bath Spa University College	BSPA	CMU
H-0049	Bolton Institute of HE	BIHE	CMU

[9] As in the year 2000

Code	Institution Name	Abbrev.	Group[9]
H-0050	Bournemouth University	BOUR	NONALIGNED
H-0051	University of Brighton	BRIG	NOTAFFILIATED
H-0052	University of Central England in Birmingham	UCE	CMU
H-0053	University of Central Lancashire	CLANC	CMU
H-0054	University of Gloucestershire	GLOUC	CMU
H-0055	London Guildhall University	LGU	CMU
H-0056	Coventry University	COV	CMU
H-0057	University of Derby	DERBY	CMU
H-0058	University of East London	UEL	CMU
H-0059	University of Greenwich	GREEN	CMU
H-0060	University of Hertfordshire	HERT	NONALIGNED
H-0061	University of Huddersfield	HUDD	NONALIGNED
H-0062	University of Lincoln	LINC	NONALIGNED
H-0063	Kingston University	KINGST	CMU
H-0064	Leeds Metropolitan University	LMU	CMU
H-0065	Liverpool John Moores University	LJMU	NONALIGNED
H-0066	Manchester Metropolitan University	MMU	NONALIGNED
H-0067	Middlesex University	MIDD	CMU
H-0068	De Montfort University	DEMONT	NONALIGNED
H-0069	University of Northumbria at Newcastle	NORTH	NONALIGNED
H-0070	University of North London	UNL	CMU
H-0071	Nottingham Trent University	NTRENT	NONALIGNED
H-0072	Oxford Brookes University	OXBR	NONALIGNED
H-0073	University of Plymouth	PLYM	NONALIGNED
H-0074	University of Portsmouth	PORT	NONALIGNED
H-0075	Sheffield Hallam University	SHU	NONALIGNED
H-0076	South Bank University	SBU	CMU
H-0077	Staffordshire University	STAFF	CMU
H-0078	University of Sunderland	SUND	CMU
H-0079	University of Teesside	TEES	CMU
H-0080	Thames Valley University	THVL	CMU
H-0081	University of West of England Bristol	UWE	NONALIGNED
H-0082	University College Chichester	CHICH	NOTAFFILIATED
H-0083	University of Westminster	WESTM	CMU
H-0084	Wimbledon School of Art	WIMB	NOTAFFILIATED
H-0085	University of Wolverhampton	WOLV	CMU
H-0086	University of Wales College Newport	NEWP	NONALIGNED

[9] As in the year 2000

Code	Institution Name	Abbrev.	Group[9]
H-0087	North East Wales Institute of Higher Education	NEWI	NOTAFFILIATED
H-0089	University of Wales Institute Cardiff	UWIC	CMU
H-0090	University of Glamorgan	GLAM	CMU
H-0091	Swansea Institute of Higher Education	SWANI	NOTAFFILIATED
H-0092	Trinity College Carmarthen	TRCC	NOTAFFILIATED
H-0095	University of Abertay Dundee	ABERT	CMU
H-0096	Edinburgh College of Art	EDCART	NOTAFFILIATED
H-0097	Glasgow School of Art	GLSART	NOTAFFILIATED
H-0100	Queen Margaret University College Edinburgh	QMU	NOTAFFILIATED
H-0101	Royal Scottish Academy of Music and Drama	RSAMD	NOTAFFILIATED
H-0104	Robert Gordon University	RGU	NOTAFFILIATED
H-0105	University of Paisley	PAIS	CMU
H-0106	Glasgow Caledonian University	GCU	CMU
H-0107	Napier University	NAPI	CMU
H-0108	Aston University	AST	NOTAFFILIATED
H-0109	University of Bath	BATH	1994GROUP
H-0110	University of Birmingham	BIRM	RUSSELL
H-0111	University of Bradford	BRAD	NONALIGNED
H-0112	University of Bristol	BRIS	RUSSELL
H-0113	Brunel University	BRUN	NOTAFFILIATED
H-0114	University of Cambridge	CAMB	RUSSELL
H-0115	City University	CITY	NOTAFFILIATED
H-0116	University of Durham	DUR	1994GROUP
H-0117	University of East Anglia	UEA	1994GROUP
H-0118	University of Essex	ESSX	1994GROUP
H-0119	University of Exeter	EXE	NOTAFFILIATED
H-0120	University of Hull	HULL	NOTAFFILIATED
H-0121	Keele University	KEEL	NOTAFFILIATED
H-0122	University of Kent at Canterbury	KENT	NONALIGNED
H-0123	Lancaster University	LANC	1994GROUP
H-0124	University of Leeds	LEED	RUSSELL
H-0125	University of Leicester	LEICS	1994GROUP
H-0126	University of Liverpool	LIV	RUSSELL
H-0127	Birkbeck College	BIRK	1994GROUP
H-0131	Goldsmiths College	GOLD	1994GROUP
H-0132	Imperial College of Science Technology	IMP	RUSSELL
H-0133	Institute of Education	IOE	NONALIGNED

[9] As in the year 2000

Code	Institution Name	Abbrev.	Group[9]
H-0134	King's College London	KING	RUSSELL
H-0135	London Business School	LBS	NOTAFFILIATED
H-0137	London School of Economics and Political Science	LSE	1994GROUP
H-0138	London School of Hygiene and Tropical Medicine	LSHTM	NOTAFFILIATED
H-0139	Queen Mary University of London	QUEMAR	1994GROUP
H-0141	Royal Holloway University of London	RHOLL	1994GROUP
H-0143	Royal Veterinary College	RVC	NOTAFFILIATED
H-0145	St George's Hospital Medical School	STGRG	NOTAFFILIATED
H-0146	School of Oriental and African Studies	SOAS	1994GROUP
H-0147	School of Pharmacy	SOPH	NOTAFFILIATED
H-0149	University College London	UCL	RUSSELL
H-0151C	Courtauld Institute of Art	COURT	NOTAFFILIATED
H-0151E	British Institute in Paris	BIP	NOTAFFILIATED
H-0151J	Institute of Advanced Legal Studies	IOALS	NOTAFFILIATED
H-0151K	Institute of Classical Studies	IOCLS	NOTAFFILIATED
H-0151M	Institute of Commonwealth Studies	IOCOM	NOTAFFILIATED
H-0151P	Institute of Germanic Studies	IOG	NOTAFFILIATED
H-0151R	Institute of Historical Research	IOH	NOTAFFILIATED
H-0151S	Institute of Latin American Studies	IOLMS	NOTAFFILIATED
H-0151U	Institute of United States Studies	IOUSS	NOTAFFILIATED
H-0151W	Warburg Institute	WARB	NOTAFFILIATED
H-0151Z	University Marine Biological Station Millport	UMBS	NOTAFFILIATED
H-0152	Loughborough University	LOUG	1994GROUP
H-0153	University of Manchester	MANC	1994GROUP
H-0154	University of Newcastle	NEWC	RUSSELL
H-0155	University of Nottingham	NOTT	RUSSELL
H-0156	University of Oxford	OXF	RUSSELL
H-0157	University of Reading	READ	1994GROUP
H-0158	University of Salford	SALF	NONALIGNED
H-0159	University of Sheffield	SHEF	RUSSELL
H-0160	University of Southampton	SOUTH	RUSSELL
H-0161	University of Surrey	SUR	1994GROUP
H-0162	University of Sussex	SUSSX	1994GROUP
H-0163	University of Warwick	WARW	1994GROUP
H-0164	University of York	YORK	1994GROUP
H-0165	UMIST	UMIST	1994GROUP
H-0167	University of Edinburgh	EDIN	RUSSELL

[9] As in the year 2000

Code	Institution Name	Abbrev.	Group[9]
H-0168	University of Glasgow	GLAS	RUSSELL
H-0169	University of Strathclyde	STRA	NOTAFFILIATED
H-0170	University of Aberdeen	ABERD	NOTAFFILIATED
H-0171	Heriot-Watt University	HERW	NOTAFFILIATED
H-0172	University of Dundee	DUND	NOTAFFILIATED
H-0173	University of St Andrews	StA	1994GROUP
H-0174	University of Stirling	STIR	NOTAFFILIATED
H-0176	University of Wales Lampeter	LAMP	NOTAFFILIATED
H-0177	University of Wales Aberystwyth	ABERY	NONALIGNED
H-0178	University of Wales Bangor	BANGR	NOTAFFILIATED
H-0179	Cardiff University	CARDF	RUSSELL
H-0180	University of Wales Swansea	SWANS	NOTAFFILIATED
H-0181	University of Wales College of Medicine	UWCM	NOTAFFILIATED
H-0184	The Queen's University of Belfast	QUEEN	RUSSELL
H-0185	University of Ulster	ULST	NOTAFFILIATED
H-0186	Univ. of Wales Centre for Adv. Welsh and Celtic Stud.	WELSH	NOTAFFILIATED
H-0187	Westhill College	WESTH	NOTAFFILIATED
H-0188	Institute of Cancer Research	ICR	NOTAFFILIATED
H-0189	Writtle College	WRITTL	NOTAFFILIATED
H-0190	Norwich School of Art and Design	NSAD	NOTAFFILIATED
H-0192	Cumbria College of Art and Design	CCAD	NOTAFFILIATED
H-0195	Royal Agricultural College	RAC	NOTAFFILIATED
H-0196	UHI Millennium Institute	UHI	NOTAFFILIATED
H-7002	Armagh Observatory	ARMA	NOTAFFILIATED
H-7003	Institute of Zoology	IOZ	NOTAFFILIATED

[9] As in the year 2000

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